NICRA-INTEGRATED MODELLING PUBLICATION

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National Innovations on Climate Resilient Agriculture (NICRA)

NICRA-INTEGRATED MODELLING: SIGNIFICANT OUTPUTS

(2016-2021)

Participating Institutions

ICAR-IARI, New Delhi (coordinating))
ICAR-CRIDA, Hyderabad
ICAR-CMFRI, Kochi
ICAR-CIBA, Chennai
ICAR-IISS, Bhopal
ICAR-IISWC, Dehradun
ICAR-IIFSR, Modipuram
ICAR-IIHR, Bengaluru
ICAR-DOGR, Rajgurunagar
ICAR-NBSS&LUP, Nagpur
ICAR-RC-NEH, Barapani
ICAR-IIWM-Bhubaneswar
ICAR-CPRI, Shimla
ICAR-NRM, New Delhi
IIT-Chennai

Studies conducted on

Crops
Water
Soil
Farming systems
Fish
Shrimp

Climate change research provides strategic information for building adaptation and resilience of systems. In addition to field and wet-lab experimentation, simulation modelling is essential to come-out with several possible situations, their impacts, delineation of vulnerable areas and possible adaptation strategies at regional level. This will help in decision making and policy setting for building resilience. In India, simulation analysis has been used for quantification of impacts of climate change on several sectors such as water, forests and agriculture. The simulation studies on annual and even on perennial crops provided essential insights on impacts of climate change. Studies also concentrated on quantifying the adaptation gains. Though these simulation efforts have led to overall understanding of the gravity of climate change impacts, and led to prioritization of climate change research in India, there is a need to use these leads for making Indian agriculture climate resilient. For doing so, the potential role of simulation modelling has to be exploited to the maximum so that adaptation strategies are derived and implemented in more scientifically integrated way. In the digital era, food production systems are fast moving towards harnessing the potential of digital agriculture.

The climate resilient systems can be developed when the climate change impacts and adaptation strategies are well-delineated. Keeping this in view an Integrated Modeling team was commissioned in 2016 under NICRA with 12 Institutes and later the team was further expanded. The team has specific objective of integrated modelling of the climate change regional impacts and derivation of adaptation and vulnerable regions using model ensembles. Major outputs are summarized in this folder.

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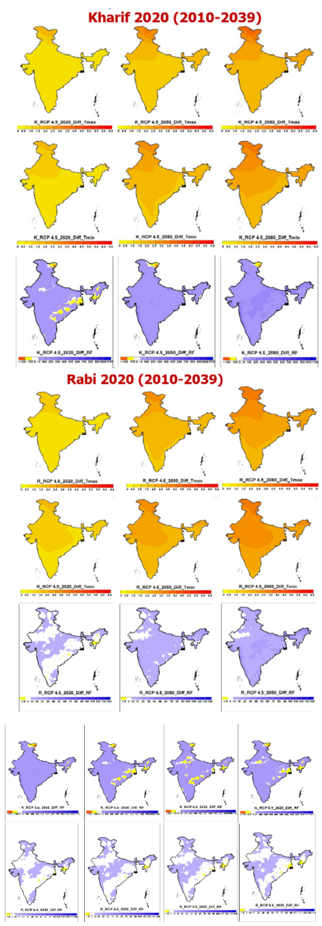
CMIP 5- 33 GCM-Ensemble seasonal climate scenarios



Seasonal projections on change in temperature and rainfall in India (Naresh Kumar et al., 2019).

Climate change projections for agricultural seasons

Seasonal climate change projections for Indian region were derived from the bias corrected probabilistic ensemble of 33 global climate models. Based on the analysis it is projected that

- Rise in minimum temperatures is to be more than rise in maximum temperatures;
- Rise in temperatures to be more during rabi than during kharif;
- During kharif, minimum temperatures to increase in the range of 0.946 - 1.061 °C (2020), 1.345-2.42 °C (2050) and 1.358-4.067 °C (2080) in different RCPs, while projected increase during rabi is 1.096-1.207 °C (2020), 1.5422.759 °C (2050) and 1.546-4.652 °C (2080);
- Maximum temperatures during kharif to increase in the range of 0.741 – 0.847 °C (2020), 1.145-2.004 °C (2050) and 1.265-3.533 °C (2080) in different RCPs while the projected increase in rabi is 0.882-0.947 °C (2020), 1.317-2.308 °C (2050) and 1. 389-4.01 °C (2080);
- Rise in temperatures are projected to be more in the northern regions of India than in the southern region;
- Rainfall projections, though less robust, indicate an increase during kharif and rabi seasons;
- Kharif rainfall is projected to increase in the range of 2.3-3.3% (2020), 4.9-10.1% (2050) and 5.5-18.9% (2080), while rabi rainfall is projected to increase in the range of 12% (2020), 12-17% (2050) and 13-26% (2080);
- Rainfall increase (%) is projected to be more during rabi than increase during kharif but the variability is projected to increase significantly in both seasons;
- Variability in terms of coefficient of variation for minimum and maximum temperatures is more during rabi than during kharif;
- The variability for maximum temperatures is projected to rise during both seasons;
- The variability for minimum temperatures to rise in kharif; while it may remain high in rabi season.

This analysis indicated a progressive climate change and increase in variability during kharif and rabi seasons in India towards the end of the century.

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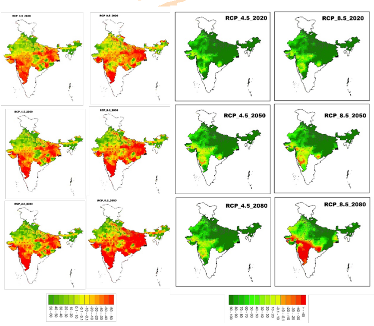
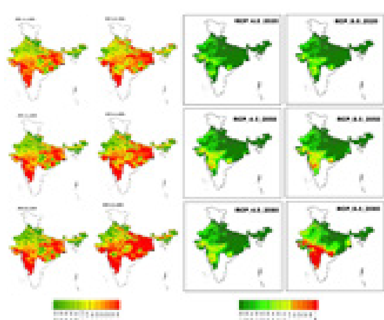
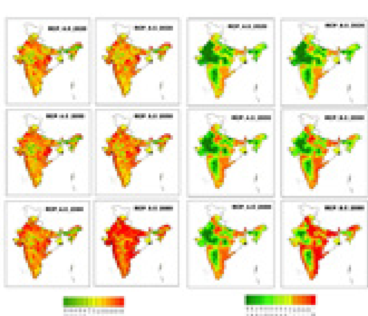
Impacts and adaptation gains -Wheat



Irrigated kharif rice



Rainfed kharif rice



Projections on impacts, adaptation and vulnerability of crops

Regional impacts of climate change, adaptation gains and adaptation options are developed for major crops.

Wheat

Without adaptation, climate change is projected to affect the wheat productivity by about -3.2 to -5.3% in 2020 (2010-2039); -8.4 to -19.3% in 2050 (2040-2069); and -18.9 to -41% in 2080 (2070-2099) under different representative concentration pathways (RCPs 2.6, 4.5, 6.0 and 8.5). States like Bihar, Jharkhand, West Bengal are particularly vulnerable. Adaptation will improve the yield at state level in the range of 10 to 40% in major wheat growing states. Varieties that maintain current crop duration can improve yield in north-west India in future climates. Developing short-duration heat tolerant varieties is important for sustaining wheat yield in central India.

Rice

The irrigated rice yield during kharif season is projected to be affected by about -3% in 2020, -2 to 3.5% in 2050 and 2 to 5% in 2080 climate scenarios in all RCPs (2.6, 4.5, 6.0 and 8.5). Rainfed rice productivity is projected to change in the range of 7 to -28% in 2020; 2 to -20% in 2050 and -10 to -47% in 2080 climate scenarios in different RCPs with significant spatial variation. Irrigated rice in states such as Haryana, Karnataka, Kerala, Maharashtra, Tamil Nadu and West Bengal is to be affected significantly without adaptation. Growing heat and water stress tolerant and short duration varieties with improved nutrient and water management can enhance the productivity up to 28% or even more till 2050 climate scenarios. However, strategy of growing short-duration varieties than the current ones in north-west India may not prove beneficial even in the near future.

Maize

For maize, under RPC 4.5 scenario a reduction of 9-10% yield (in 2020), 10 - 19% (in 2050) and > 20% (in 2080 scenario) in comparison to baseline (year 2010) in the major maize growing districts is projected. Change in sowing time is one of the adaptation options tested.

Soybean

Soybean productivity is projected to increase despite climate change, marginally by 2.5 to 5.5% in 2020 scenario across all RCPs; while in 2050 scenario the projected increase is in the range of 3-10% and in 2080 scenario, the projected change is up to 14% across all RCPs (2.6, 4.5, 6.0 and 8.5). This increase in yield, however, has a significant inter-annual variability. Adaptation with short-duration varieties, supplemental irrigation, raised bed method of planting, etc can significantly reduce the inter-annual variability as well as improve the yields up to 40%.

Potato

The yield potential of potato varieties is projected to decrease spatially from Punjab to West Bengal and also in part of MP and Gujarat. Delaying the planting up to 2 weeks in 2050's and 1 to 3 weeks in 2080's can offset the reduction in yield at most of the locations. Under low elevations the stolon initiation may delay by 10 days as compared to higher altitude (1600-2400 m above MSL). Kufri Girdhari performed better in higher altitude as compared to Kufri Jyoti, which was found to perform better in low altitude.

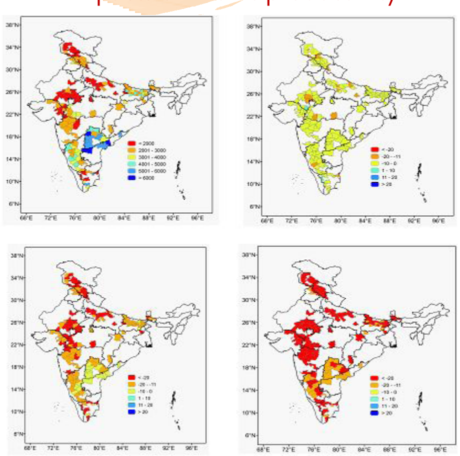
Onion

The InfoCrop-onion model was calibrated and validated satisfactorily for south and central Indian regions. The onion yield is projected to be affected in Bangalore and Indore regions, while in Dharwad and Pune regions, marginal yield advantages are projected for kharif and late kharif season. In Nasik region, late kharif and rabi yields are likely to decline.

Studies and projections on diseases and insect pests

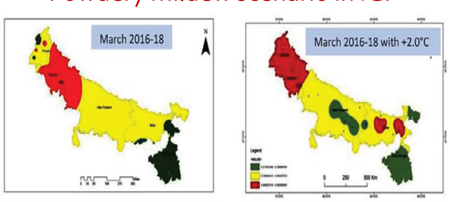
- Developed a disease forecasting system for spot blotch of wheat and leaf blast of rice. The climatic conditions in western zone are favorable for powdery mildew incidence in wheat only during March. The simulation analysis indicated that the disease is likely to be restricted in the western zone, and marginally change in the eastern plains in future climates.
- Developed and validated BPH forewarning methodology that specifies that more frequent rains during June-September months (≥30 days) might play significant role in BPH outbreaks. Higher rainfall accompanied with cloudy weather and lower sunshine hours results in favorable temperature and relative humidity conditions for BPH development.
- Population dynamics simulation model of wheat aphids was developed to couple with InfoCrop v2.1-wheat model to simulate crop-pest interactions. The forewarning system of brown plant hopper is validated for Delhi region.

Impacts on maize productivity

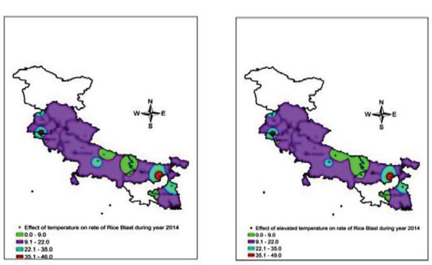


Deviation in 2050 Deviation in 2080

Powdery mildew scenario in IGP

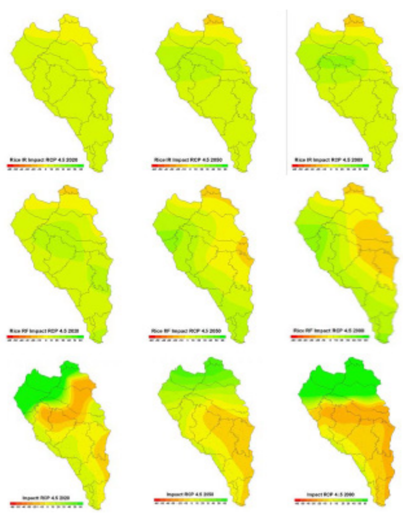


Powdery mildew scenario in IGP

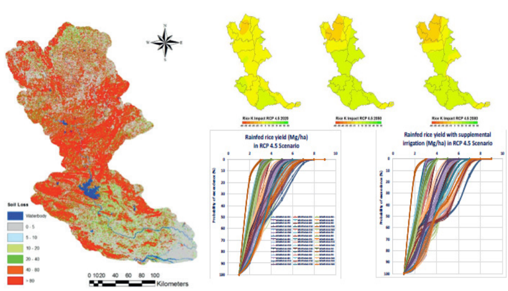


A: current B: With +1.5°C

Impacts on productivity of irrigated (top) and rainfed (middle) rice, and wheat (bottom) in Ramganga river basin in RCP 4.5 2020, 2050 and 2080 scenarios



a) Soil erosion potential & b) climate change impacts on kharif rice in Brahmani river basin and yield benefits due to supplemental irrigation



a b

Projections at river basin level (river flows, irrigation water requirement, soil erosion, crop management)

Ramganga

Integrated assessments for river basins indicated that in Ramganga river basin, maximum mean monthly water yield is projected to increase by 8 to 41 % in monsoon months, while during months of March, October and December maximum decrease in mean monthly water yield by 1 to 59 % during the 2020s, 2050s and 2080s is projected. Wheat yield may improve in upper catchment areas even with current management conditions. But in middle and lower catchment areas, wheat yield is projected to reduce substantially. Irrigation water scarcity during December to affect wheat yield in middle and lower sub-basins.

Brahmani

In Brahmani river basin, the simulation analysis projected an increase in stream flow that varied from 1.4 to 2.4%, 8.0 to 13.2%, and 7.0 to 21.3% except during January and February during 2020, 2050, and 2080 climate scenarios of all RCPs. An increase in high flows is also projected. Further, shifting of low erosion class to moderate to high erosion class was indicated. The potential soil loss in the Brahmani river basin is projected to be up to 320 t ha^{-1} yr^{-1} where maximum area has soil loss rate more than 80 t ha^{-1} yr^{-1} and these are extreme erosion potential areas. Crop simulation analysis indicated that during kharif season, application of one supplemental irrigation provides an opportunity to improve yield from 4.5 Mg ha^{-1} to 6 Mg ha^{-1} at a similar probability level of 40%.

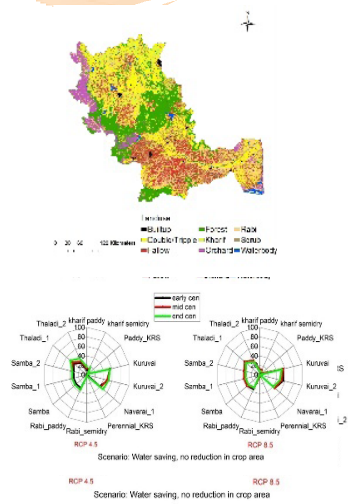
Betwa

The composite hydrologic indices (CHI) were developed for evaluating the recharge potential in the Betwa river basin. More than half of the basin area is dominated with high runoff potential zone and is suitable for selecting rainwater harvesting structure. Suitable sites for water harvesting structures in each hydrologic response Unit (HRU) having possibilities to increase the groundwater level are identified.

Cauvery

Simulation results indicate unmet water demand reduction during 50% of the time period spanning from 1976 – 2005 with maximum unmet demand during 2002, 2003 in Cauvery river basin, A reduction in the magnitude of flows in future is projected with possible influence on acreage under rice and sugarcane crops. Altering acreage under water-intensive crops such as sugarcane increases the possibility of successful production of other crops. Water rotation, crop diversification with less water requiring crops, implementation of water saving techniques and augmentation of existing reservoirs through inter-basin diversions are possible ways to ensure effective water management in Cauvery river basin.

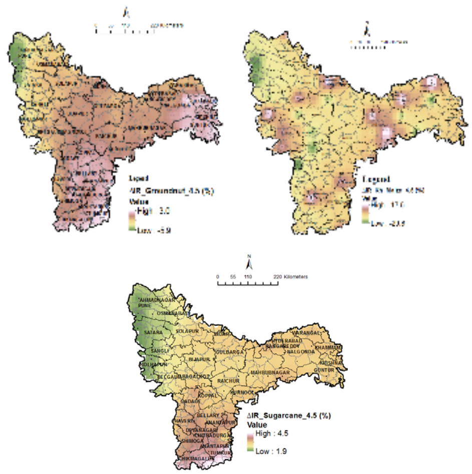
Water management options in Cauvery river basin



Krishna

Irrigation water requirement of crops in Krishna river basin under RCP 4.5 and 6.5 in 2030 climate scenarios is projected to change for chickpea (increase by 1.8 to 3.2 %; 1.9 to 5.4%), rabi sorghum (-7.1 to 10.6 %;-0.2 to 14.5%), pigeon pea (-10.7 to 7.6 %; -9.3 to 12.7%), maize (-29.8 to 17.5%; -28.3 to 17.9 %), pearl millet (-2.5 to 7.2 %; -0.9 to 9.1%), sunflower (-9.6 to 9.9 %; -10.4 to 11.9%), ground nut (-5.9 to 3.0%; -4.2 to 3.5%), kharif rice (-3.0 to 2.3%; -2.5 to 1.5%) and sugarcane (1.9 to 4.5%; 1.4 to 4.0%).

Impacts on irrigation water demand of groundnut, irrigated kharif maize and sugarcane in Krishna river basin



Watershed-level modeling

In Brapani of Meghalaya, soil loss in eight micro-watersheds is projected to increase in future climate scenarios.

An optimization program was developed for the Badajor watershed in Brahmani river basin area and found that 28% allocation of groundwater in the monsoon season and 72% allocation of groundwater in post-monsoon season were found optimum for maximization of net return.

Farm-level modeling

The farm level modeling projected a decline in sugarcane yield in 60% of the farms in the range of 10-15 % in Meerut region in Uttar Pradesh. However, in remaining farms the yield increase is projected to be around 7-10 % compared to baseline.

Soil health management

The simulation analysis indicated that for soils low in soil organic carbon (SOC), threshold value to maintain SOC is ~10% residue retention for adequately fertilized crops (100% N applied). For a N limited crop, it is as high as 30%. The conditions where SOC were higher (1%), approximately 60% residue retention is the threshold level for N limited condition. This level is 30% and 20% in case of medium and high level of N management, respectively. Addition of inorganic fertilizer in combination with FYM could be an important strategy in maintaining the SOC and thus the soil quality.

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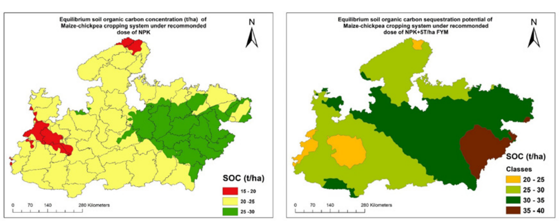
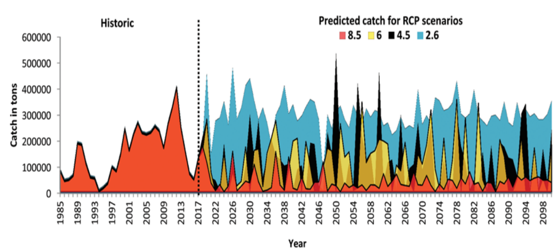
Equilibrium SOC concentration in maize – chickpea cropping system with (a) recommended dose and (b) NPK+ FYM



Catch forecast of Indian oil sardine under all RCPs



InfoCrop v2.1 Home Page

Marine fisheries and shrimp aquaculture

A Fisheries Oceanography interdisciplinary model was used to explain the inter-annual variability of Indian Oil Sardine from 1992 to 2015 in terms of upwelling during southwest monsoon and mixed layer temperature during pre-monsoon along the south-west coast of India. Catch per unit effort of Indian west coast fishery is linearly linked to the chlorophyll frontal area while inversely related to the thermal frontal area. Sea surface temperature (SST) anomaly over the west coast linearly linked with the El Nino Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD) events.

During the ENSO period, temperatures over the south-west coast go beyond 27 °C while during co-occurred events of El Niño and the Positive IOD temperatures go beyond 28 °C. Co-occurrence and strong events of IOD and ENSO lead to a decrease in the fishery of Indian oil sardine along the south-west coast of India (example 1990 to 1999 years).

Oil sardine fishery will increase due to the increase in upwelling intensity and chlorophyll-a enhancement while it will decease along the southwest coast of India due to the strong events of ENSO and IOD (example, 2000 to 2007 years).

In Tamil Nadu during November, frequent extreme weather events are projected and it is suggested to complete the shrimp crop harvest early. Similarly, increasing temperatures with no significant change in rainfall at many places indicate less availability and poor quality of water for aquaculture.

The Life Cycle Assessment studies indicated the need to reduce or find an alternative to fish meal use in shrimp feed production, and use efficient pumps and generators.

Models developed/ updated under NICRA

- **InfoCrop 2.1:** updated and released. More than 2500 scientists/ students in 46 countries have downloaded this model.
- **InfoCrop-Onion:** The models is revised, calibrated and validated for south and central India. The **disease forecast models** have been developed for spot blotch of wheat and leaf blast of rice.
- **Crop-pest coupled models**: Pest population dynamic models for rice-BPH and wheat-aphids were coupled to

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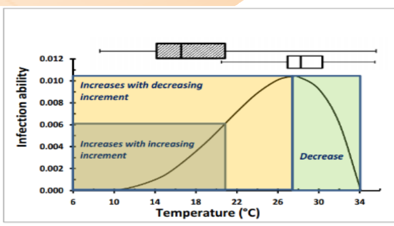
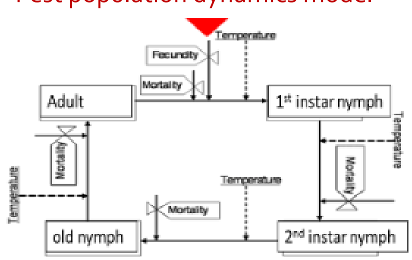
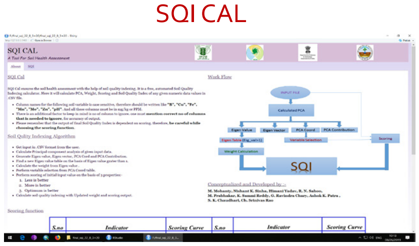
Disease forecast model



Pest population dynamics model



SQI CAL



Carry Cap

InfoCrop-wheat and rice models, respectively to simulate crop-pest interactions.

- Loose coupling of hydrological model with crop model is done
- An **optimization model** was developed for the Badajor watershed area for optimal conjunctive water allocation of canal and groundwater for maximization of net returns.
- A software "**SQI CAL**" for rapid calculation of soil quality index is developed.
- The **multi-gear biomass dynamic model** (multi-species) is developed, calibrated and validated the model for selected fishery resources of India.
- **System dynamic models** were developed for growth, feed digestion, and carbon and nitrogen dynamics of **shrimp aquaculture.**
- **CarryCap,** a web based tool is updated to estimate the optimum farming area for brackish water species on a particular water source.

Contributions/ papers/ bulletins/ trainings/ HRD

- Part of these studies are being contributed to India's Third National Communication to UNFCCC and IPCC reports, etc.
- Research papers published: 40 (highest NAAS rating- 17.47 (impact factor 11.47); papers with NAAS rating > 8- 12, papers with NAAS rating > 6- 23.
- Technical Bulletins: 3
- Book Chapters: 12
- Trainings programmes organized: 4 (over 135 students and scientists are trained).
- Students trained (MSc/ PhD): 6; RA/SRF/YP trained: 25

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